AD-A153 709 EOQ (ECONOMIC ORDER QUANTITY) RANGE MODEL(U) AIR FORCE LOGISTICS MANAGEMENT CENTER GUNTER AFS AL D J BLAZER ET AL. JAN 85 AFLMC-LS840612 SBI-AD-F630 708 1/1

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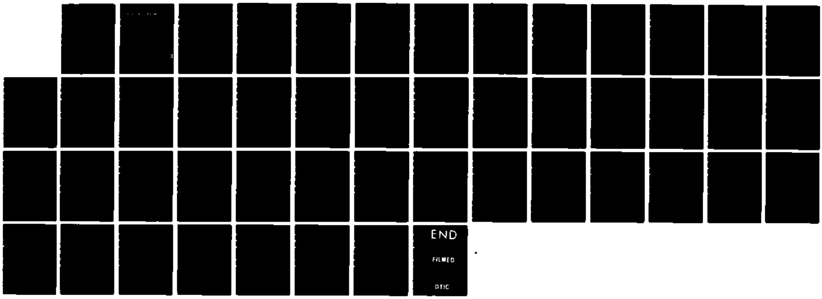

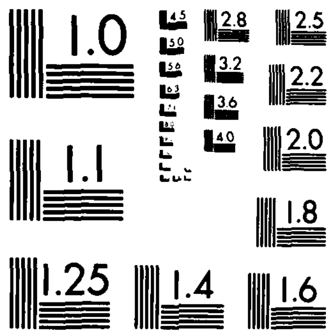

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EOQ RANGE MODEL

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ABSTRACT

We examined the current method to determine the range of stock at base level and compared it to another range model we call a hybrid model. We analyzed the performance of the current range model by reviewing historical USAF supply performance data and by conducting a sensitivity analysis. We then compared the current range model performance to our hybrid model. We showed that by implementing a hybrid model, we can achieve increased performance levels. Our hybrid model will decrease grounding incidents by up to 2% worldwide. We documented the mission, stockage, and cost impact of implementing our hybrid model.

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EXECUTIVE SUMMARY

In compliance with DOD Instruction 4140.45, the Air Force implemented range model in December 1981 that was based on economics. This economic range model determines what items to stock at base level, by comparing the cost to stock the item to the cost to not stock the item. The item is stocked if it is economical. In this report we determine the:

a. Performance of the current range model,
b. Sensitivity of the range model to cost, item, and other factors, and
c. Operational, stockage, and cost performance of an alternative method of determining the range of stock for base level.

We measured the performance of the current range model and found we had increased the number of line items we stock, but we have not increased the unit issue effectiveness. We also found General Support Division items with large lot sizes and high unit prices have a lower likelihood of stocking with the current range model than they did before the model was implemented. The reason the unit issue effectiveness is low is because the current range model is a customer model; it favors individual customers rather than satisfying the quantity of individual items all customers--large and small--request.

The Air Force has some exceptions to the purely economic part of the current range model. We stock on the first grounding incident or high priority awaiting parts request. Our analysis showed almost 44% of the items currently stocked were stocked as an exception rather than meeting the current range model criteria. We found the shortage costs are too low in the current range model. DOD guidance states the penalty cost can be used as a "**tuning knob**" to ensure the model reaches some performance goal. We did just that to develop an alternative range model, which we call a hybrid model.

We developed the hybrid model from two models--a customer and a unit model. We assigned shortage costs to a backordered customer in the customer model and different shortage costs to a backordered unit in the unit model. We set the shortage cost to achieve the following performance targets:

Mission Impact Code	Subsequent Demand Effectiveness Target Line (%)	Unit (%)
1	100	100
2	80	98
3	60	94
4	56	81

Subsequent demand effectiveness is the percent of items which have a demand level greater than zero and have subsequent demands.

Our hybrid model stocks many items sooner than the current range model and will decrease grounding incidents for consumable items by up to 2%. These benefits will cost $14 million for General Support Division and $2.1 million for System Support Division.

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CHAPTER 1

THE PROBLEM

INTRODUCTION:

The Air Force Logistics Management Center is charged with analyzing existing stockage policy and making recommendations that will improve base-level logistics. This report marks the completion of our cradle to grave analysis of the current base-level inventory models for consumable or economic order quantity items. We analyzed the current system and alternative depth models [2,4,5,6] which determine how much to stock for those items we stock. We analyzed how long to stock or when to stop stocking consumable items [9]. In this report, we analyze the range of stock, which is the determination of when we should start stocking an item.

Many of our previous studies' recommendations have been implemented. As a result the Air Force will stock more of an item for a longer period of time. More importantly, implementation will result in a significant increase in fully mission capable rates. The number of grounding incidents resulting from an out-of-stock condition **for items that we decide to stock** will be significantly reduced. When all of our recommendations are implemented, there will be little marginal benefit to increasing the depth of stock. However, there is still potential for increasing the fully mission capable rate by stocking more items.

PROBLEM STATEMENT:

In this report, we examine the current and alternative methods of determining the range of stock at base-level to answer the following questions:

a. How is the current range model performing?
b. How sensitive is the range model to changes in cost, item, and other factors?
c. What is the operational, stockage, and cost performance of alternative methods of determining the range of stock?

BACKGROUND:

Under DoD direction, as a result of the Retail Inventory Mangement and Stockage Policy (RIMSTOP) report, the Air Force implemented a new range policy in December 1981. DoD guidance indicated an item should be stocked based on economic criteria. DODI 4140.45, Standard Stockage Policy for Consumable Secondary Items at the Intermediate and Consumer Levels of Inventory, identifies a model to find "**the mix of stock that will minimize the total variable cost for a specified performance goal [7].**" DODI 4140.45 also states that stockage policy "**will be based upon the minimization of total variable costs whenever practical and consistent with peacetime opeations and war readiness considerations.**"

The Air Force implemented its current range model in December 1981. The current range model compares the cost to stock to the cost to not stock. If the cost to stock is less than the cost to not stock, the item is stocked. We describe the cost equations below, the actual formulas and details are shown in Appendix A.

Economic Range Model

$$\text{Cost To Not Stock} = \begin{matrix}\text{Number of}\\ \text{Customer Orders}\\ \text{Per Year}\end{matrix} \times \left(\begin{matrix}\text{Time Weighted}\\ \text{Shortage Cost}\end{matrix} + \begin{matrix}\text{End Use Order}\\ \text{Cost}\end{matrix}\right) \quad (1)$$

$$\text{Cost to Stock} = \text{Cost to Add} + \text{Cost to Maintain} + \text{Holding Cost Per Year} + \text{Order Cost} +$$

$$\begin{matrix}\text{Number of}\\ \text{Customer Orders}\\ \text{Per Year}\end{matrix} \times \left(\begin{matrix}\text{Percent of time}\\ \text{Backordered}\end{matrix}\right) \times \left(\begin{matrix}\text{Time}\\ \text{Weighted}\\ \text{Shortage}\\ \text{Cost}\end{matrix} + \begin{matrix}\text{Back}\\ \text{Order}\\ \text{Cost}\end{matrix}\right) \quad (2)$$

The current range model is influenced by the variable cost measures (holding cost, order cost, etc.). We computed these variable costs in accordance with DoD guidance. The development of the variable costs is documented in [8].

The Air Force range model implemented in December 1981, included a policy to stock on the first grounding incident or the first high priority awaiting parts (AWP) request. This drove exceptions to the current range model that were "consistent with operational and wartime requirements."

CHAPTER 2

ANALYSIS

OVERVIEW: We document our analysis in four sections. In the first section, we measure the **performance of the current range model**. In the second section, we summarize the results of a **sensitivity analysis** of the current range model. In the third section, we develop and compare **the performance of an alternative range model**. In the final section we discuss **implementation issues**.

PERFORMANCE OF THE CURRENT RANGE MODEL

In this section, we measure the performance of the range model implemented in December 1981. The full impacts of this change are reflected in FY83 and FY84. We begin by showing the percent of items with a demand level, and the issue and stockage effectiveness at base level both before and after the current range model's implementation. Issue effectiveness is the unit fill rate for all items requested at base level. Stockage effectiveness is the unit fill rate for all items **stocked** at base level. Table 2-1 portrays the results for Systems Support Division (SSD) items, which are Air Force Logistics Command supported items. Table 2-2 portrays the results for General Support Division (GSD) items.

Range Model Performance
(Percent)

SSD

	FY 1981	FY 1982	FY 1983	FY 1984
Items With Demand Level	32.2	30.2	38.9	37.0
Issue Effectiveness	63.0	62.8	62.7	62.6
Stockage Effectiveness	80.8	80.7	80.1	80.9

Table 2-1

Range Model Performance
(Percent)

GSD

	FY 1981	FY 1982	FY 1983	FY 1984
Items With Demand Level	28.5	27.6	32.3	30.2
Issue Effectiveness	68.0	67.6	68.7	68.6
Stockage Effectiveness	86.1	86.3	88.4	88.9

Table 2-2

The percentage of both SSD and GSD items stocked increased as a result of the current range model (implemented December 1981). In fiscal year (FY)1982, the Air Force also implemented a policy to update the cost variables used to compute the economic order quantity (EOQ). As a result of the new EOQ cost variables, the depth of stock increased for some less expensive items, and thus the stockage effectiveness for GSD items increased. However the issue effectiveness did not increase for either SSD or GSD items.

We next conducted a statistical analysis of items at England AFB. We used item record data from FY1982 (before the new range model fully took effect) and compared it to item record data from FY1983. We compared the demand, price, stockage priority code, and lot size of the items stocked in FY1982 to the same characteristics for items stocked in FY1983. We wanted to determine if there was a change in the characteristics of items stocked as a result of the new range model. Table 2-3 presents the results for both SSD and GSD.

Comparison Results

SSD	GSD
Same demand characteristics	Same demand characteristics
Average unit price ($168.00) was similar for all items	Average unit price ($25.00) for all items were similar
Same percent of high priority items (22%)	Same percent of high priority items (5%)
Fewer low priority items stocked in 83	Fewer low priority items stocked in 83
Lot size and price of stocked items not significantly different	Lot size and price of stocked items significantly different

Table 2-3

As Table 2-3 shows, the items at England AFB displayed the same demand characteristics--the same average number of customer orders and the same daily demand rates--in FY1982 as in FY1983. In addition, the unit prices of items from FY1982 to FY1983 were similar (there was a slight increase in price for higher priced items). There were the same number of high priority items in FY1982 as in FY1983. Note that SSD items have a much higher percentage of high priority items (22%) than GSD items (5%). For both GSD and SSD, there were fewer low priority items stocked in FY1983 than in FY1982. Finally there was no statistical difference between the lot size (the average number of units demanded) and the price of stocked items for SSD, but there was a significant difference for GSD. For example, the average lot size for stocked GSD items at England AFB in FY83 was 8.55 versus an average lot size for non-stocked items of 21.39.

We draw two conclusions from our analysis of the performance of the current range model policy.

a. The current range model reduces the probability of stocking items with large lot sizes and high unit price. There was a statistically significant difference for GSD items. For example, the average unit price for stocked GSD items at England AFB in FY83 was $19.78 versus an average price for non-stocked items of $53.80.

b. Exceptions to the current range model significantly influence the stockage of SSD items. We define exceptions to be those items that are stocked but do not economically qualify for stockage (i.e., stock on the first grounding incident). There are three exceptions to economically stocking an item. They are (1) stock if the SPC is 1, (2) stock if there is a bench stock detail on file based on consumption, and (3) the number of demands is 12 or greater. SSD items are much higher priced than GSD and also have significantly more high priority items. The policy to stock on the first grounding incident or high priority AWP incident effects a larger number of SSD items. We show this more clearly in a later section.

These two conclusions explain why the unit issue effectiveness has not increased even though the number of line items stocked has increased, and in the case of GSD, the unit stockage effectiveness has increased. The current range model determines that it is not "economical" to stock items with a large number of units demanded, thus lowering the unit fill rate.

The reason the current range model does not stock items with a large number of units demanded is that it is a customer model not a unit model. Examine equations (1) and (2) again. The penalty cost of a backorder is assigned to the number of customer orders per year not the number of units backordered. Therefore a customer who backordered 100 units is assigned the same shortage cost as a customer who backordered 1 unit.

Based on our analysis of the current range model performance, we investigated the following questions regarding the current system:

a. Can the current range model be modified so there are fewer economic exceptions?
b. Can we modify the current range model to acheive a certain specified customer and unit performance?

SENSITIVITY ANALYSIS

Our first step was to conduct a sensitivity analysis on the current range model. Our goal was to determine the impact of changing the factors that drive the range model. We did this by comparing the cost to stock to the cost to not stock for an item when all but one input factor is held constant. We summarize our conclusions here, the detailed results are documented in Appendix B.

We conducted sensitivity analyses on the following factors:

Variable Cost Factors:

End use order cost
Cost to maintain

Cost to order
Back order cost
Cost to add
Shortage cost

Item Factors:

Unit price
Number of customer orders
Lot size

Other Factors:

Essentiality code
Stockage priority code
Order and ship time

We draw the following conclusions from our analysis:

a. The current range model is not very sensitive to changes in the cost factors except for the shortage costs.
b. The shortage costs in the current range model are too low.
c. The current range model is sensitive to item factors:

(1) The lower the unit price of an item, the higher the probability of stocking.
(2) The greater the number of customer orders per year, the higher the probability of stocking.
(3) The lower the lot size, the higher the probability of stocking.

d. The current range model is sensitive to changes in the stockage priority code.

The stockage priority code and shortage costs are related, in that the shortage costs are a constant amount for each stockage priority code. Table 2-4 shows the current shortage cost for each stockage priority code.

Current Range Model Shortage Costs

Stockage Priority Code	Shortage Costs($)
1	35
2	25
3	10
4-5	4

Table 2-4

DoD guidance states [7], "that the shortage cost can be adjusted until a desired performance is obtained and still retain the feature of optimal

allocation of funds." This guidance referred to the performance within selected stockage segments, but it applies equally to the overall performance of the range model.

In summary, we know that the range model is sensitive to item factors and the shortage costs. Item factors are independent variables and cannot be controlled, so that leaves the shortage costs as the most logical and effective factor to vary to improve the performance of the range model. In the next section we develop an alternative range model by varying the shortage costs.

PERFORMANCE OF AN ALTERNATIVE RANGE MODEL

We know from the previous two sections the unit fill rate has not increased as a result of implementing the current range model, because the current model is a customer model. We also know the current range model's shortage costs are too low. We developed an alternative range model, which we call a hybrid model, because it includes both a unit and customer model. Our alternative range model also increases the shortage costs. The current range model computes a time-weighted shortage cost (reference Equations (1) and (2)). The shortage cost is multiplied by the order and ship time (O&ST) as a fraction of a year. Since the average CONUS O&ST is 17 days, the penalty cost is multiplied by .047 (17/365). Thus time weighting actually lowers the impact of the shortage. In the hybrid model we delete time weighting--the shortage cost is a one-time penalty cost for not satisfying a customer demand. We document our model in Appendix C.

In Table 2-5, we compare the results of our hybrid model to the current range model (considering only economics) and to the current range model with all the stockage exceptions. We used actual data from England AFB to run the models. We used one year's data to determine whether to stock an item and measured the performance using the subsequent six months of data. For example, assume there are two items--one we stocked and one we did not stock. Assume that for the stocked item, there was another customer order for two units in the next six month period. For the non-stocked item, there was also another customer order but for a quantity of one. The subsequent demand line item effectiveness for these two items is 50% (1 item stocked out of 2 requested) and the subsequent demand unit effectiveness is 66.7% (2 units stocked out of 3 requested). Table 2-5 displays the performance for all the items from England AFB.

Alternative Range Model Performance

(England AFB)

MODEL	LINE ITEMS STOCKED	SUBSEQUENT DEMAND LINE ITEM EFFECTIVENESS (%)	SUBSEQUENT DEMAND UNIT EFFECTIVENESS (%)	DEMAND LEVEL ($)
Current Range Model (Economics only)	4126	35.1	66.0	$1.5M
Current Range Model with Exceptions	7329	55.6	77.7	$2.5M
Hybrid Model	9133	68.1	91.1	$2.65M

TABLE 2-5

A total of 4,126 line items economically qualify for stockage with just the economic part of the current range model, yet England had 7,329 line items with a demand level. **ALMOST 44% OF THE ITEMS STOCKED AT ENGLAND AFB ARE EXCEPTIONS TO THE CURRENT RANGE MODEL.** Also note from Table 2-5 that by stocking 1804 more items (9133-7329), we can increase the line item and unit fill rates by more than 12% for $150,000. **WE CAN SIGNIFICANTLY INCREASE BOTH THE LINE ITEM AND UNIT ISSUE EFFECTIVENESS AT A RELATIVELY SMALL COST.**

We developed our hybrid model by varying the shortage costs to reach a given performance level. We used the criteria in Table 2-6 to set our performance level.

PERFORMANCE LEVEL CRITERIA

MISSION IMPACT CODE	SUBSEQUENT DEMAND EFFECTIVENESS RATE LINE (%)	UNIT (%)
1	100	100
2	80	98
3	60	94
4	56	81

TABLE 2-6

Appendix D provides the detailed analysis that shows how we developed the hybrid model. We also show in Appendix D a series of sensitivity analyses on

SENSITIVITY ANALYSIS RESULTS
(3 Orders Per Year)

UNIT PRICE \ LOT SIZE	1	2	4	8	16	32	64	128	256	512
.50	XXXXX	XXXXX	XXXXX	XXXXX	XXXXX					
1.00	XXXXX	XXXXX	XXXXX	XXXXX						
2.00	XXXXX	XXXXX	XXXXX							
4.00	XXXXX	XXXXX								
8.00	XXXXX									
16.00										
32.00										
64.00										
128.00										
256.00										

ORDERS PER YEAR = 3

SHORTAGE COST = $35

ORDER & SHIP TIME = 20 DAYS

XXXXX INDICATES ITEM WILL BE STOCKED

FIGURE B-1

By examining Table B-3 and the cost to stock and cost to not stock for each of the different sensitivity analyses, we found that the range model is not very sensitive to changes in the variable costs with the exception of the shortage costs. Recall the shortage costs are driven by the stockage priority code. Thus when stockage is dependent on the SPC in Table B-3, it is actually the shortage costs that are affecting stockage. Note from the fourth column of Table B-3, there is some sensitivity to the essentiality code, the end use order cost and the cost to maintain. The cost to maintain is the cost incurred to maintain a level of stock support for an item. The essentiality code and end use order cost are actually part of the penalty cost for being out of stock (reference Appendix A). It is more logical to use the penalty cost (comparing the shortage cost, end use order cost and essentiality code) to fine tune the range model performance than to use the cost to maintain. Since the range model is relatively insensitive to changes in the other cost variables and item factors cannot be changed, we varied the shortage cost to develop alternatives.

SENSITIVITY ANALYSIS OF ITEM FACTORS

In Part Two, we conduct a sensitivity analysis of the item factors; unit price, number of customer demands, and lot size. We set all cost factors to current values as documented in AFM 67-1 (see Appendix A). We used an order and ship time of 20 and 50. We then varied one item factor at a time as shown in Table B-4.

Item Factor Values

Factor	Starting Values	Incremented Values
Unit Price	$.50	multiplied by 2 up to $256.
Number of Customers	1	2,3,4,5,6,10,20.
Lot Size	1	multiplied by 2 up to 512.

TABLE B-4

Figure B-1 and B-2 summarize the results of an analysis on item factors. For these two figures, we used a shortage cost of $35 which is the largest value currently used by the economic range model.

Sensitivity Analysis Results

Code and Description	High Demand High Price	High Demand Low Price	Low Demand High Price	Low Demand Low Price
L O&ST	Not Stock	Stock when: SPC=1,2,3 $L \geq 24$; SPC4	Not Stock	Not Stock
E Essentiality Code	Not Stock	Stock	Not Stock	Stock when: E=4,5; SPC1
U End Use Order Cost	Not Stock	Stock when: $U \geq 4.65$; SPC1 $U \geq 5.35$; SPC2 $U \geq 6.15$; SPC3 $U \geq 7.08$; SPC4	Not Stock	Stock when: $U \geq 14.23$; SPC1,2 $U \geq 17.21$; SPC3,4
F Cost to Maintain	Not Stock	Stock when: $F \leq 57.87$;SPC1 $F \leq 37.85$;SPC2 $F \leq 18.82$;SPC3 $F \leq 10.46$;SPC4	Not Stock	Stock when: $F \leq 4.05$;SPC1 $F \leq 3.52$;SPC2 $F \leq 2.31$;SPC3 $F \leq 1.75$;SPC4
A Cost to Order	Not Stock	Stock when: $A \leq 8.14$; SPC1 $A \leq 7.08$; SPC2 $A \leq 4.65$; SPC3 $A \leq 4.05$; SPC4	Not Stock	Not Stock
B Back Order Cost	Not Stock	Stock when: $B \leq 24.89$;SPC1 $B \leq 16.36$;SPC2 $B \leq 7.08$; SPC3 $B \leq 2.66$; SPC4	Not Stock	Not Stock
G Cost to Add	Not Stock	Stock when: $G \leq 43.53$;SPC1 $G \leq 32.91$;SPC2 $G \leq 12.38$;SPC3 $G \leq 3.52$; SPC4	Not Stock	Not Stock

TABLE B-3

Parameter Settings

	High Demand High Price	High Demand Low Price	Low Demand High Price	Low Demand Low Price
Number of Customer Orders	20	20	1	1
Demand per Order	500	500	1	1
Unit Price	$500	$.50	$500	$.50

TABLE B-2

We used an order and ship time of 30 days for all runs and we used all stockage priority codes for each set of parameters. We incremented all variable costs by multiplying the current previous cost by 1.15. We repeated this 20 times. When we measured the sensitivity of order and ship time, we incremented the order and ship time by 1 day 30 times. Finally we varied the essentiality code from 1 to 5. Table B-3 summarizes the results.

TYPE FACTOR	FACTOR	DESCRIPTION
Item	Unit Price (C)	The price charged for the item.
	Number of Customer Orders (S)	How many times a customer ordered the item.
	Lot Size	How many units the customer ordered when he ordered the item. The lot size is: $\frac{\text{Total Units Demanded}}{\text{Number of Customer Orders}}$.
Other	Order and Ship Time (L)	Average elapsed time between the initiation and receipt of stock replenishment requisitions.
	Stockage Priority Code	A code assigned based on the urgency justification code of the request.
	Essentiality Code (E)	A measure of an item's worth in terms of how its failure would affect mission accomplishment. Currently the essentiality code value is 1.

TABLE B-1 (Continued)

We first increased the effect of the cost and other variables. We ran the model to determine the effect in four categories of items. We categorized the items with the set parameters described in Table B-2.

SENSITIVITY ANALYSIS
FACTORS

TYPE FACTOR	FACTOR	DESCRIPTION
Variable Cost	End Use Order Cost (U)	Costs incurred when priority requisitions are submitted back to the source of supply to fill specific, high priority customer requirements. Currently the cost is $8.38.
	Cost to Maintain (F)	Costs incurred to maintain an item with a level of stock support. Currently the cost is $15.98.
	Cost to Order (A)	Costs incurred for processing routine stock replenishment orders. Currently the cost is $19.94 for local purchase and $5.20 for all other sources of supply.
	Back Order Cost (B)	Costs incurred to establish a routine due-out. Currently the cost is $3.60.
	Cost to Add (G)	Costs incurred to compute a level of stock to support an asset. Currently the cost is $5.54.
	Shortage Cost (Z)	This is a variable cost factor that can be altered to drive model performance. It is, by design, a "tuning knob" by which the range model's performance may be altered. Currently the cost values are: Stockage Priority Code — Shortage Cost ($) 1 — 35 2 — 25 3 — 10 4-5 — 4

TABLE B-1

APPENDIX B

SENSITIVITY ANALYSIS

OVERVIEW

We conducted a two-part sensitivity analysis of all the factors in the current EOQ range model. Part One was to analyze the sensitivity of cost variables and other factors. Part Two was to analyze the sensitivity of item factors. Our purpose was twofold:

a. To determine how the current range model is affected by changes in the factors in the model.

b. To determine which factors can be used to modify the model, thereby improving its performance.

SENSITIVITY OF VARIABLE COST FACTORS

We conducted our sensitivity analysis by holding all the factors constant except one, which we steadily increased. The factors we examined are explained in Table B-1 [1].

APPENDIX B

SENSITIVITY ANALYSIS

5. If the item or group has no demand level, the results from the above computations are compared to determine whether or not a level should be computed (unless the item is assigned stockage priority code 1, consumption type bench stock details, or an EOQ item with 12 or more demands).

a. If cost to not stock is less than cost to stock, no demand level is computed.

b. If cost to not stock is greater than or equal to cost to stock, a level is computed and stored on the appropriate item record.

c. There are three conditions when an economic comparison is not made. A demand level will always be computed when:

(1) The SPC is 1.
(2) There is a bench stock detail on file based on consumption.
(3) The number of demands is 12 or greater.

d. If an item is in an *I&S Group, the highest stockage priority* code (SPC) within the group will be used when computing an EOQ level.

APPENDIX A

THE CURRENT EOQ RANGE MODEL

1. If the cost to not stock equals the cost incurred when an item is not stocked a level will not be computed or carried against the item.

2. Cost to stock equals the cost incurred when a level is computed and carried against an item.

3. Cost computation formulas and symbols.

a. Cost to Not Stock = S (EZL + U).

b. Cost to Stock = $F + (R - DL + \frac{Q}{2})\ IC + \frac{D}{Q}\ A + S\ (1 - P)\ (EZL + B) + G$.

4. Stock Level Computation Symbols.

SYMBOL	DESCRIPTION	SOURCE	VALUE
A	Cost to order	Constant	Local purchase item = $19.94. All others = $5.20.
B	Back order cost	Constant	$3.60.
C	Unit price	Item Record	
D	Cumulative Recurring Demands (CRD)	Computed	
E	Essentiality Code	Constant	1 (one).
F	Cost to maintain	Constant	$15.98.
G	Cost to add	Constant	$5.54.
I	Holding cost rate	Constant	15 percent.
L	Average order & ship time (O&ST) in years	Computed	Priority group three O&ST from the item record source of supply routing identifier record divided by 365.
P	Line item availability	Constant	0.9.
Q	Economic order quantity	Computed	
R	Reorder Point (ROP)	Computed	Order and ship time quantity PLUS safety level quantity.
S	Total demands per year	Computed from demand frequency rate (DDFR X 365)	
U	End of use order cost	Constant	$8.38.
Z	Shortage Cost	Constant for each stockage priority code	1=$35, 2=25, 3=10, 4=4.

APPENDIX A

THE CURRENT EOQ

RANGE MODEL

CHAPTER 3

CONCLUSIONS/RECOMMENDATIONS

CONCLUSIONS

1. The current range model has increased the number of line items stocked but has not significantly increased the Air Force's supply support as measured by issue effectiveness.

2. There are almost as many items stocked at base level that are exceptions to the economic part of the current range model as there are items stocked that meet the economic criteria to stock.

3. The current range model is sensitive to four factors. There is a higher probability of stocking an item as;

   a. The shortage cost increases,
   b. The price decreases,
   c. The number of customer orders increases, and
   d. The number of units demanded per customer order decreases.

4. The current shortage costs are too low.

5. The shortage costs should be used as a tuning knob to meet a certain performance criteria.

6. A hybrid model that considers both the number of customer orders and the number of units demanded is better suited to meet Air Force mission requirements.

7. A hybrid model will decrease weapon system grounding incidents caused by consumable items by an estimated 1.5% Air Force-wide.

8. A hybrid model will cost $14 million for General Support Division items and $2.1 million for System Support Division items.

RECOMMENDATIONS

1. Implement a hybrid model to determine the range of stock at base level. (OPR: HQ USAF/LEY; OCR: DSDO/LGS)

2. Approve, implement and use the mission impact code in the hybrid range model. (OPR: HQ USAF/LEY; OCR: DSDO/LGS)

identify mission impact. As we pointed out [6], the SPC is transient; it is downgraded if there are periods of demand inactivity. Thus the shortage cost for an item that grounds a weapon system will also be lowered. We recommend the mission impact code be used instead of the stockage priority code in the range model.

We document the stock fund impact of implementing the hybrid model in Appendix E. We project an inventory augmentation requirement of $14 million for General Support Division and $2.1 million for the Systems Support Division.

our hybrid model that we ran to ensure the hybrid model meets our performance criteria without stocking so soon that excesses are generated. We show in Appendix D, that 79% of the stocked items had subsequent demands within the next 6 months under both the current system and the hybrid model. Thus the **HYBRID MODEL WILL STOCK MORE ITEMS, BUT WILL NOT GENERATE A HIGHER PERCENTAGE OF EXCESSES THAN THE CURRENT MODEL.**

We also measured the direct mission impact of our hybrid model. We used actual data from England and Kunsan AFBs to determine the number of weapon system grounding incidents that could have been prevented by using the hybrid model. Using item record data, we selected all the items that caused a grounding incident between September 1983 and March 1984, but were not stocked at these two bases in September 1983. We ran these MICAP causing items through the hybrid model to determine how many would have been stocked before September 1983 using the hybrid model. Table 2-7 displays the results.

DIRECT MISSION IMPACT WITH THE HYBRID MODEL

	BASE	
	ENGLAND	KUNSAN
Number of Items Causing Grounding Incidents	1,016	3,914
Number of Grounding Incidents Prevented By the Hybrid Model	22	44
Percent Reduction	2.0%	1.1%

TABLE 2-7

By stocking items sooner, **THE HYBRID MODEL WILL DECREASE GROUNDING INCIDENTS BY UP TO 2%.**

In summary, **THE HYBRID MODEL BETTER SUPPORTS THE AIR FORCE MISSION.** The model complies with DOD guidance by using the shortage costs as a tuning knob to meet performance goals. Finally it insures low-cost, high-demand items are stocked.

IMPLEMENTATION ISSUES

We discuss two implementation issues in this section--the use of mission impact codes in the range model and the stock fund impact.

In our EOQ Mission Impact Report [6], we developed a coding scheme that identifies an item's impact on mission performance. In that report, we indicated the mission impact codes should be used to help determine the range of stock. The current range model uses the stockage priority code (SPC) to

SENSITIVITY ANALYSIS RESULTS
(6 Orders Per Year)

UNIT PRICE / LOT SIZE	1	2	4	8	16	32	64	128	256	512
.50	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX									
1.00	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX									
2.00	XXXXXXXXXXXXXXXXXXXXXXXXXXXXX									
4.00	XXXXXXXXXXXXXXXXXXX									
8.00	XXXXXXXXXXXXXX									
16.00	XXXXXXXXX									
32.00	XXXX									
64.00										
128.00										
256.00										

ORDERS PER YEAR = 6 SHORTAGE COST = $35

ORDER & SHIP TIME = 20 DAYS XXXXX INDICATES ITEM WILL BE STOCKED

FIGURE B-2

We selected 3 and 6 orders per year, because they correspond to the extreme points in the previous Air Force range model. Prior to the December 1981 range model, all stockage priority code 1 items were stocked on the third customer order. Previously, all items with 6 customer orders were stocked regardless of the stockage priority code. As Figure B-1 shows, if the lot size is 1 for each of the three customer orders, the economic range model will

stock the item providing the unit price is $8.00 or less. Or if the unit price is $.50, then the economic range model will stock the item if the average lot size is 16 or less.

For Figure B-2, if there are 6 orders per year with a lot size of 1, the economic part of the current range model will stock all items costing $32 or less. Conversely if the cost is $.50, then the current range model will stock up to a lot size of 128. Note for both Figures B-1 and B-2 the shortage cost is the highest currently used.

The figures show the current range model is sensitive to the item factors. We draw the following conclusions:

a. The higher the unit price, the lower the probability of stocking an item.
b. The larger the lot size, the lower the probability of stocking an item.
c. The lower the number of customer orders, the lower the probability of stocking an item.

From conducting the sensitivity analysis, it is easy to see why there are so many items currently stocked as exceptions to the current range model. In Figure B-3 we show a unit price frequency diagram for all stockage priority code 1 items at England AFB.

UNIT PRICE FREQUENCY DIAGRAM FOR SPC 1 ITEMS
(ENGLAND AFB)

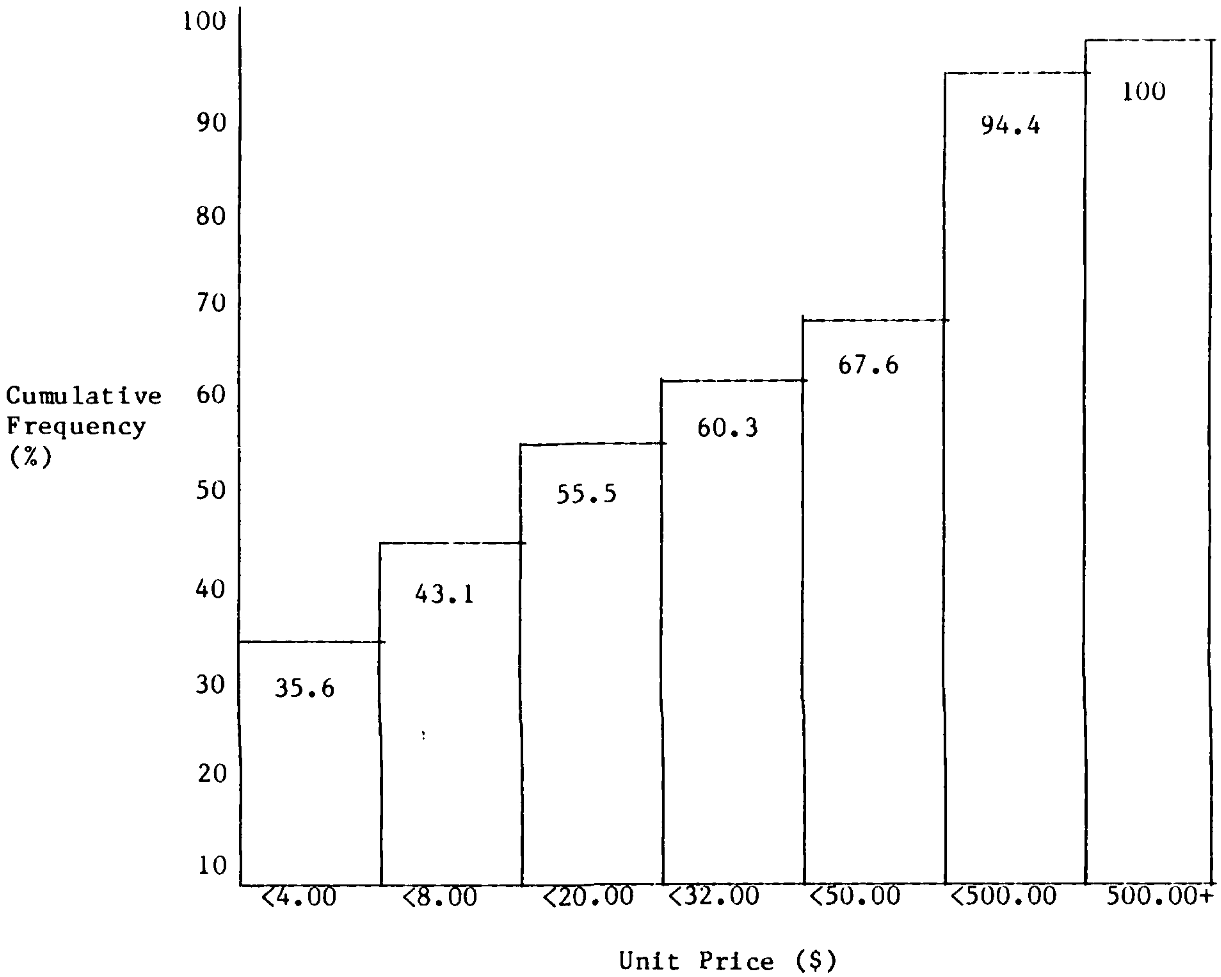

FIGURE B-3

Note that 56.9% of the items cost more than $8 (refer to Figure B-1). With the current range model, even with three customer orders, these items would not economically qualify for stockage. **THESE ITEMS GROUNDED A WEAPON SYSTEM, YET THEY DO NOT ECONOMICALLY QUALIFY TO BE STOCKED.** Even if these items had 6 customer orders, 39.7% would not qualify for stock (items that cost more than $32). And we are assuming a lot size of 1--the best case for stockage! **CLEARLY THE SHORTAGE COST IS TOO LOW.** Further, consider that Air Force policy was to run these items through the range model after 90 days and if they did not economically qualify for stockage, we lowered the demand level and reported the item partially excess. We corrected that policy based on the recommendations in the AFLMC "EOQ **Excess**" study [9].

SUMMARY

It is clear from this sensitivity analysis that our current range model needs improvement. We found that the model is sensitive to item factors and the shortage costs. Since item factors are independent variables and cannot be controlled by stockage policy, then the shortage cost is the factor to use to modify the model. It is also clear that the current shortage costs are too low.

APPENDIX C

HYBRID RANGE MODEL

APPENDIX C

HYBRID RANGE MODEL

In this Appendix, we document the hybrid range model. The hybrid model is actually two models - a customer model and a unit model. The model compares the cost to stock to the cost to not stock with the customer model. If the decision is to not stock, the model compares the cost to stock to the cost to not stock with the unit model. If it is economical to stock with the unit model, the item is stocked.

Besides the addition of the unit model, there are three other significant differences in the hybrid model. The hybrid model uses a one time shortage cost rather than a time weighted shortage cost. In the current range model, the shortage cost is multiplied by the average order and ship time (O&ST) as measured in years. The average O&ST for CONUS bases is 17 days [3], hence the O&ST in years is .047 (17/365). Thus time weighting actually lowers the impact of the shortage cost. Since we already know the shortage costs are too low, we delete the time weighting to increase the impact of the shortage costs.

The next significant difference is the use of the actual line item availability factor. The current range model uses a 90% availability factor. The availability factor is dependent on the C factor (safety level multiplier), and therefore should be different for varying C factors. The hybrid model uses an availability factor of .84 for items with a C factor of 1 and .977 for items with a C factor of 2.

The final significant difference is a constraint on stocking some items which have had only one customer order. We continue to stock on the first MICAP or high priority awaiting parts demand, however we place a constraint on all items with lower mission impact codes. The constraints are shown in Table C-1.

CONSTRAINTS FOR STOCKING ON FIRST DEMAND

Mission Impact Code	Do Not Stock On First Demand If:
2	Unit Price > $10
3	Unit Price > $1
4-5	Do Not Stock

TABLE C-1

Thus a mission impact code 2 item with only 1 demand that is priced over $10 is not run through the hybrid model. If the item is less than $10, it is run through the hybrid model and **stocked only if it economically qualifies for stockage**.

1. Cost computation formulas and symbols.

a. Cost to Not Stock.

Customer Model: $S(Z_c + U)$.

Unit Model: $DZ_u + SU$.

b. Cost to Stock.

Customer Model: $F + (R - DL + \frac{Q}{2})\ IC + D/Q\ A + S(1-P)\ (Z_c + B)$.

Unit Model: $F + (R - DL + \frac{Q}{2})\ IC + D/Q\ A + (1-P)\ (DZu+SB)$.

2. Stock Level Computation Symbols.

SYMBOL	DESCRIPTION	SOURCE	VALUE
A	Cost to Order	Constant	Local purchase item = $19.94. All Others = $5.20.
B	Backorder Cost	Constant	$3.60:
C	Unit Price	Item Record	
D	Cumulative Recurring Demands (CRD)	Computed	
F	Cost to Maintain	Constant	$15.98
G	Cost to Add	Constant	$5.54
I	Holding Cost Rate	Constant	15 percent
L	Average Order and Ship Time (O&ST)	Computed	
P	Line Item Availability	Constant for each C factor	C = 1; P = .84. C = 2; P = .977.
Q	Economic Order Quantity	Computed	
R	Reorder Point (ROP)	Computed	Order and Ship Time Quantity Plus the C factor times the Safety Level Quantity.

S	Total Demands Per Year	Computed from Demand Frequency Rate (DDFR X 365)	
U	End of Use Order Cost	Constant	$8.38.
Z_c	Customer Model Shortage Costs	Constant for each mission impact code	2 = 25, 3 = 23, 4 = 10.
Z_u	Unit Model Shortage Costs	Constant for each mission impact code	2 = .8, 3 = .4, 4 = .15.

3. If the item or group has no demand level, the results from the above computations are compared to determine whether or not a level should be computed (unless the item is assigned a mission impact code of 1, consumption type bench stock details, or an EOQ item with 12 or more demands).

a. If the cost to not stock is less than the cost to stock in both the customer and unit model; no demand level is computed.

b. If the cost to not stock is greater than or equal to the cost to stock in **either** the customer or unit model, a level is computed.

c. There are three conditions when no economic comparison is made and the item is **not** stocked. A demand level will not be computed for items with one customer order and:

(1) The mission impact code is 2 and the unit price is greater than $10.
(2) The mission impact code is 3 and the unit price is greater than $1.
(3) The mission impact code is 4 or 5.

d. There are three conditions when an item is stocked and no economic comparison is made. A demand level will always be computed when:

(1) The mission impact code is 1.
(2) There is a bench stock detail on file based on consumption.
(3) The number of demands is 12 or greater.

e. If an item is an I&S Group, the highest mission impact code within the group will be used in computing an EOQ level.

f. Mission impact code 5 items are not considered for stockage.

APPENDIX D

HYBRID MODEL DEVELOPMENT

APPENDIX D

HYBRID MODEL DEVELOPMENT

In this appendix, we explain the development of the hybrid model and document its performance with data from six Air Force bases. Our approach was to use the shortage costs as a "tuning knob" to reach a given performance level. By increasing the shortage costs, we can stock more items and thereby increase the model's performance. However, the higher the shortage costs, the more inventory investment required. The issue is where should we set the performance level.

We used an aggregate exchange curve [10] to determine the performance level to reach by increasing the shortage costs. An aggregate exchange curve is a tool used by managers to make aggregate inventory decisions by trading off the benefit gained to the cost [10]. Using data from England AFB, we developed aggregate exchange curves for stockage priority codes (SPC) 2, 3, and 4 items. We excluded SPC 1 items since we automatically stock items that ground a weapon system. Figure D-1 presents the exchange curve for SPC 2 items.

LINE ITEM EFFECTIVENESS
AGGREGATE EXCHANGE CURVE
(England AFB)
SPC 2

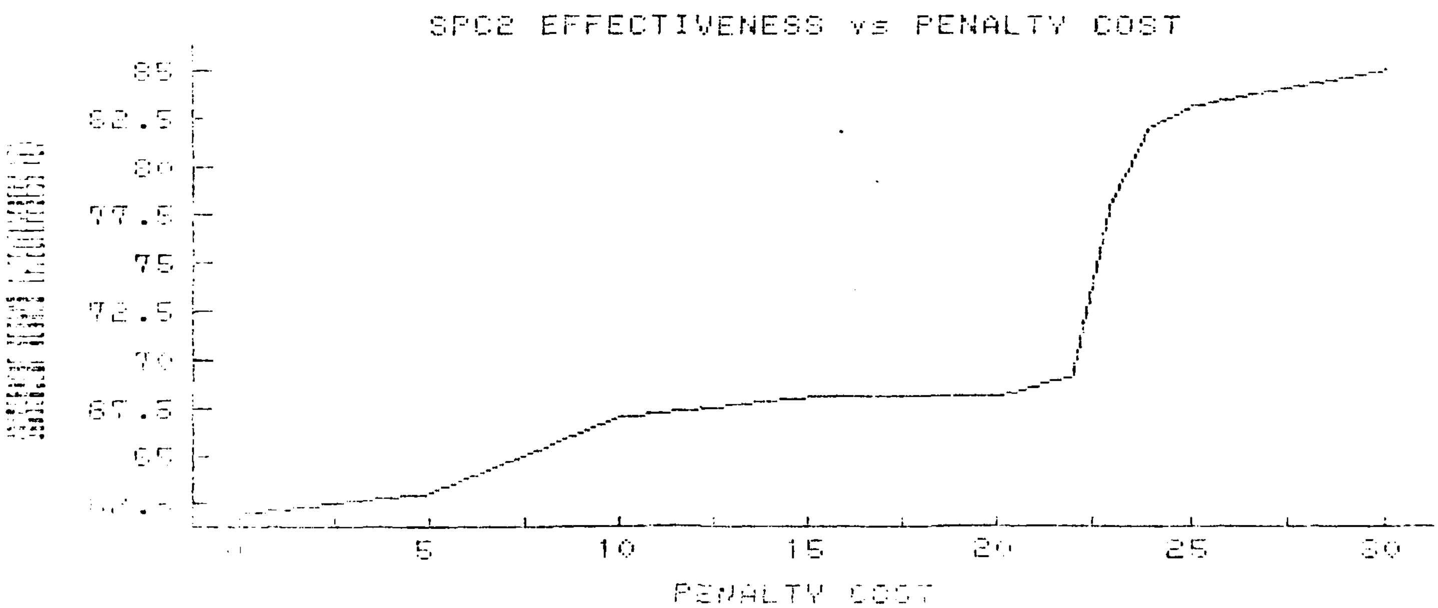

FIGURE D-1

Note that as we increase stock by increasing the shortage cost, the subsequent demand line item effectiveness increases. However as the line item

effectiveness increases above 82%, the marginal gain by increasing stock declines sharply. The 82% effectiveness corresponds to a shortage cost of $25.

We concluded that we should increase the line item effectiveness to 82% for these SPC 2 items.

Since we reached the marginal increase limit on line item effectiveness, the next area to explore was unit issue effectiveness. We wanted to find an approach to satisfy additional Air Force mission requirements by improving unit issue effectiveness.

Since the customer model has a bias against items with a large number of units demanded per customer order, we developed a unit model. The unit model is virtually the same as the customer model except the shortage cost is applied to the units backordered. The problem is what should the unit shortage costs be? We again use an exchange curve to determine the unit shortage cost. Figure D-2 shows the exchange curve for SPC 2 items.

UNIT EFFECTIVNESS EXCHANGE CURVE
(England AFB)
SPC 2

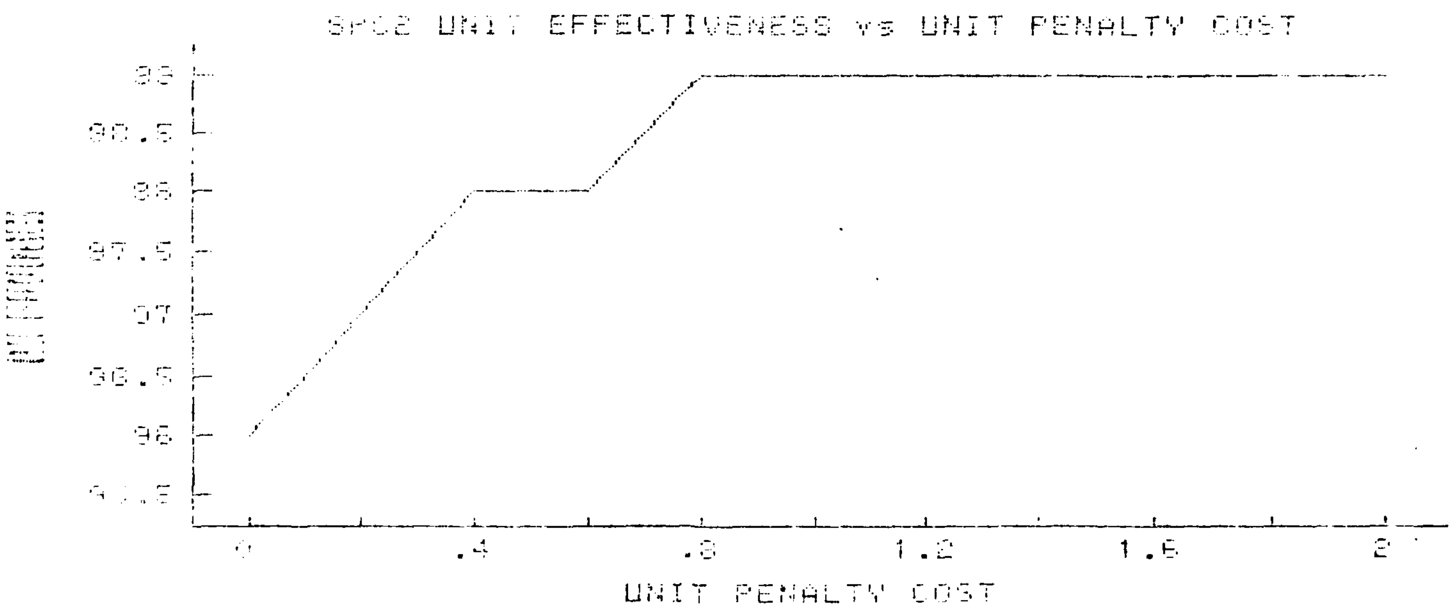

FIGURE D-2

As Figure D-2 shows, the customer portion of the hybrid model generates a 96% unit effectiveness rate. By using the unit model we can increase the unit fill rate to 99% before the curve flattens out. To increase the subsequent demand unit effectiveness rate beyond 99% will require significantly more dollars. The unit shortage cost that corresponds to 99% is $.80.

We conducted the same steps for stockage priority code 3 and 4 items. Figure D-3 and D-4 present the aggregate exchange curve for SPC 3 and SPC 4 items respectively.

LINE ITEM EFFECTIVENESS
AGGREGATE EXCHANGE CURVE
(England AFB)
SPC 3

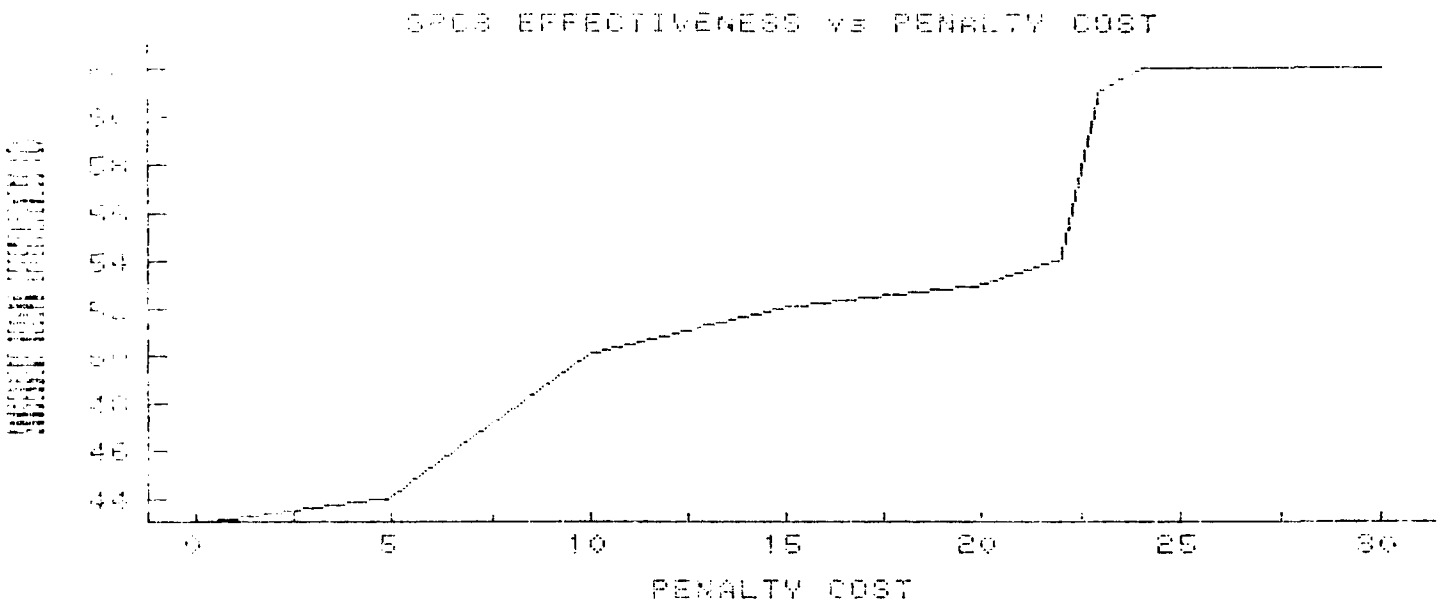

FIGURE D-3

LINE ITEM EFFECTIVENESS
AGGREGATE EXCHANGE CURVE
(England AFB)
SPC 4

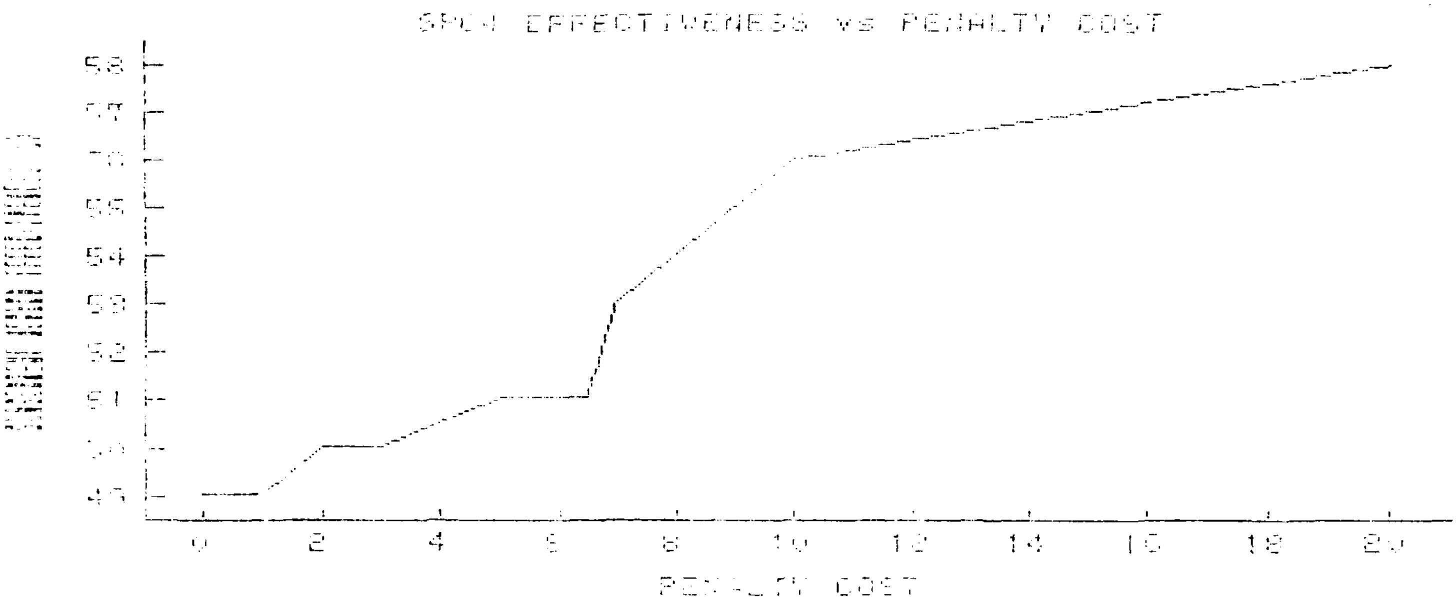

FIGURE D-4

For SPC 3 items, the marginal increase in line item effectiveness benefit declines beyond 60% and for SPC 4 items, the marginal benefit declines after 56%. This corresponds to shortage costs of $23 and $10 respectively. We next developed exchange curves (Figure D-5 and D-6) to determine the unit shortage costs.

UNIT EFFECTIVENESS EXCHANGE CURVE
(England AFB)
SPC 3

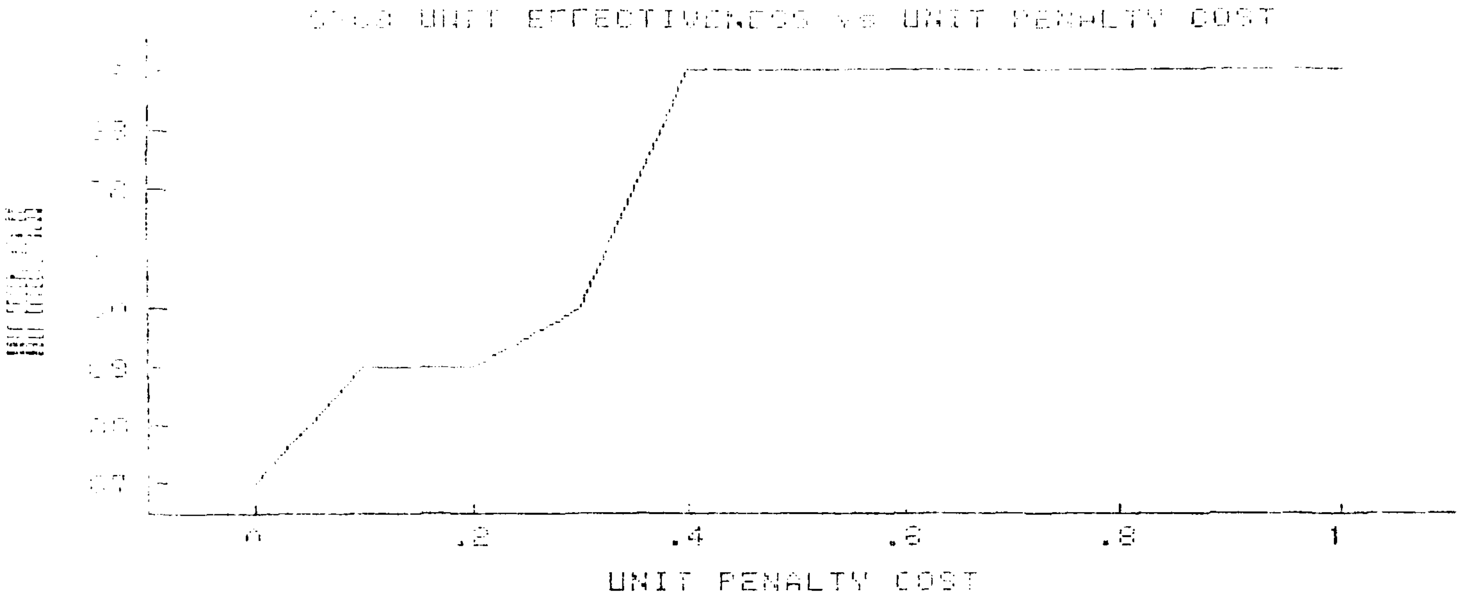

FIGURE D-5

UNIT EFFECTIVENESS EXCHANGE CURVE
(England AFB)
SPC 4

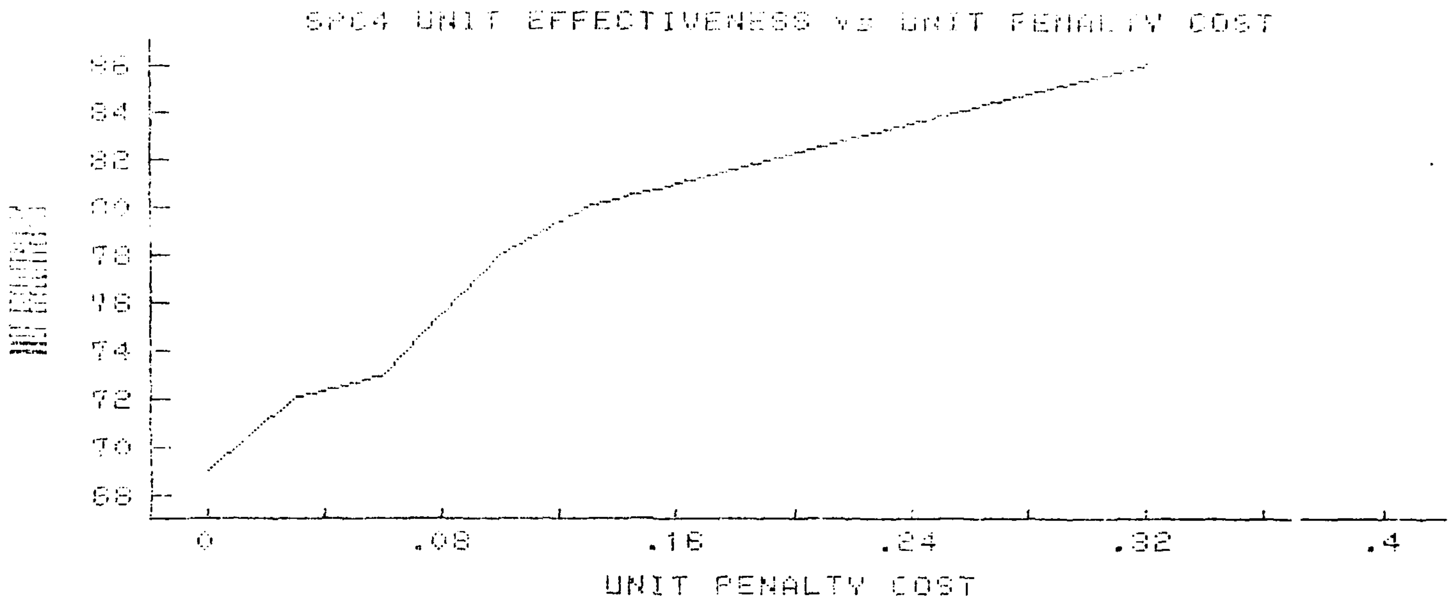

FIGURE D-6

As Figure D-5 and D-6 indicate, the unit effectiveness curve flattens out at 94% for SPC 3 items and 81% for SPC 4 items. The corresponding unit shortage costs are $.40 and $.15 for SPC 3 and SPC 4 items respectively.

We summarize the hybrid model performance in Table D-1. Using data from five Air Force bases, we compare the performance of the hybrid model to the current range model. We present the number of line items stocked, the subsequent demand line and unit effectiveness, and the incremental increase in the dollar value of the demand level.

HYBRID MODEL PERFORMANCE
(SPC 1 through 4)

BASE	MODEL	LINE ITEMS STOCKED	SUBSEQUENT DEMAND LINE ITEM EFFECTIVENESS (%)	SUBSEQUENT DEMAND UNIT EFFECTIVENESS (%)	Δ DEMAND LEVEL ($)
Little Rock	Current	13,223	57.4	87.0	-
	Hybrid	16,686	70.5	95.9	$320K
Minot	Current	13,333	52.8	86.0	-
	Hybrid	16,855	66.3	93.8	$267K
Randolph	Current	8,798	54.8	86.5	-
	Hybrid	11,187	67.9	96.2	$219K
Kunsan	Current	10,810	48.6	69.3	-
	Hybrid	16,913	69.9	95.1	$823K
Upper Heyford	Current	13,200	52.2	78.0	-
	Hybrid	19,008	73.4	97.0	$525K

TABLE D-1

THE HYBRID MODEL WILL SIGNIFICANTLY IMPROVE BASE-LEVEL SUPPORT. The hybrid model will increase the number of line items stocked and increase the line item effectiveness by over 13% and the average unit effectiveness by more than 12%. Note the improvement is more significant at overseas bases. **THE CURRENT RANGE MODEL BIASES AGAINST STOCKAGE AT OVERSEAS BASES.** The current range model computes the penalty cost portion of the cost to stock by weighting the shortage cost by the percent of time an item is backordered. The current range model assumes 10% of the time an item is backordered (refer to Appendix A), and that 10% is used for both CONUS and overseas bases. However, we use a C factor of 2 overseas which increases the amount of on-hand inventory and decreases the percent of backorders. Increasing on-hand inventory increases the cost to stock, and by not decreasing the stock-out percentage, the cost to stock is again increased. Therefore an item with the same demand and price characteristics will be economical to stock at a CONUS base and not economical to stock overseas. The stock-out percentage factor should be adjusted according to the C factor [1]:

C FACTOR	STOCK-OUT PERCENTAGE
1	.16
2	.023
3	.01

The hybrid model uses the correct stock-out percentages (refer to Appendix C), therefore the hybrid model performance will not be biased against overseas bases.

We next analyzed the hybrid model to insure it was at least as good a predictor of future demand as the current model. We did this by analyzing the percentage of items that were stocked and that had a subsequent demand. Using 12 months of data from six Air Force bases, we determined which items would be stocked with the hybrid model and then recorded the percentage of items that had a demand in the subsequent 6 month period. Table D-2 displays the results by stockage priority code.

PERCENT OF ITEMS STOCKED BY THE HYBRID MODEL WITH SUBSEQUENT DEMANDS

	BASE					
SPC	ENGLAND	LITTLE ROCK	MINOT	RANDOLPH	KUNSAN	UPPER HEYFORD
2	85	90	87	89	94	82
3	69	80	68	61	70	75
4	81	81	78	87	76	75

TABLE D-2

We next compared the percent of items stocked with subsequent demands from the hybrid model to the current range model. Table D-3 displays the results for England AFB.

PERCENT OF ITEMS STOCKED WITH SUBSEQUENT DEMANDS
(England AFB)

SPC	CURRENT RANGE MODEL	HYBRID MODEL
2	82	85
3	66	69
4	83	81
Overall	79	79

TABLE D-3

Overall, the hybrid model is at least as good a predictor of subsequent demands as the current range model, and better predicts demands for the higher priority items. The hybrid range model will stock more items, but will not generate any higher percentage of excesses than the current range model.

APPENDIX E

STOCK FUND IMPACT

APPENDIX E

STOCK FUND IMPACT

In this appendix we document the stock fund impact of implementing our hybrid range model. We first computed the percentage increase in the dollar value of the demand level for the six bases we used. Table E-1 displays those results.

PERCENT INCREASE IN DEMAND LEVEL DOLLAR VALUE

	ENGLAND	LITTLE ROCK	MINOT	RANDOLPH	KUNSAN	UPPER HEYFORD	AVERAGE
Systems Support	1.09	1.19	1.28	.43	2.40	.75	1.190
General Support	2.53	2.42	2.98	3.20	5.13	3.51	3.295

TABLE E-1

We included all the recent changes to the SBSS demand level in our *calculations*. The next step is to determine the current Air Force General Systems Division and Systems Support Division demand level totals. According to the AF Consolidated Stock Fund Report (M20) dated 31 March 1984, the Air Force demand level totals are:

General Support Division: $323.1 million .
System Support Division: $151.2 million .

These totals are the summation of the safety level quantity, the order and ship time quantity and the operating level. Since the March 84 totals do not include the inventory augmentation for the EOQ cost variables and the revised safety level, we must add those totals. Thus the new demand level totals are:

Baseline + EOQ Cost Variables + Safety Level:

GSD: 323.1 + 38.0 + 57.6 = $418.7 million .
SSD: 151.2 + 7.0 + 19.3 = $177.5 million .

We next apply the average increase (from Table E-1) to the GSD and SSD totals. Even though the percent increase in the demand level dollar value is higher for overseas bases, we used the averages from Table E-1 because the percent of overseas bases in our sample (33%) corresponds to the percent of overseas bases in the Air Force. Thus the inventory augmentation for implementing the hybrid range model will be:

GSD: 418.7 X .03295 = $13.80 million .
SSD: 177.5 X .01190 = $ 2.11 million .

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